APPLICATIONS OF COMPUTER MAPPING TO POLICE OPERATIONS

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Abstract: *Computer mapping is a rapidly developing technique that can assist police departments in a variety of ways. Computer mapping techniques can be classified into three general categories: descriptive, analytical and interactive mapping. Descriptive mapping shows data in a pin map or shaded area format. Analytical mapping starts with analysis of data followed by automatically displaying the results on a map. such as the identification and display of crime "hot spots" in a city. Interactive mapping allows a user to cycle through a series of steps starting with making queries against a database, mapping the results, making a decision from the maps and starting anew with another query. This chapter provides examples of each type, with emphasis on how computer mapping can assist police operations. The final sections discuss the steps necessary to establish a computer mapping system, and what we can expect in the future.*

Computerized mapping is a rapidly developing technology that assists police departments in strategic planning, operations and crime analysis. In this chapter, we explore the benefits of computerized mapping by describing a variety of applications for police departments. These applications range from the production of simple pin maps to interactive mapping for geographical analysis.

This chapter has four major sections. First, an overview of the evolution of mapping technology in the law enforcement field is presented. Second, several mapping techniques used by law enforcement agencies are dis-

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cussed. Examples are provided from police department analysts, geographers, researchers and others involved in analyzing police data. Third, the process for developing an automated mapping system is discussed. The final section argues that the capabilities afforded by mapping technologies have several implications for future strategies and tactics of police departments.

AN OVERVIEW OF COMPUTER MAPPING IN LAW ENFORCEMENT

Automated or computerized mapping has a history of only about 25 years, although manual pin maps of crime, traffic accidents and other police events have a longer history. Early applications of automated crime mapping (Pauly et al.. 1967; Carnaghi and McEwen. 1970) showed the potential for automated visual representations of crime and traffic accidents. Later publications on crime analysis strongly advocated geographic analysis of crime (Chang et al., 1979; Buck et al., 1973), and illustrated practical applications of geographic analysis (Brantingham and Brantingham, 1981; Harries, 1974; Pyle, 1974; LeBeau, 1987).

More recent efforts expand mapping into new areas. Of particular relevance is the work on "hot spots," which demonstrates the concentration of activities in certain geographical areas (Spelman, 1988; Sherman et al., 1989; Sherman and Weisburd. 1989; Maltz et al., 1990; Green, 1993; Block, 1993). Sherman et al. (1989) examined the concentration of police calls and found that calls for predatory crime occur in a few hot spots. Spring and Block (1987) confirmed the importance of geography and crime. As noted by Block (1993:34), mapping allows for the explorations of the "high vulnerability of some neighborhoods or demographic groups" and crime events. It thus contributes to an increased understanding of how certain environments contribute to criminality.

Further advances in the use of mapping have involved the examination of the clustering of specific forms of criminal behavior in different sites. Major advances are summarized by Weisburd et al. (1991) and by Block (1993). Computer mapping techniques allow for the examination of the spatial relationships among the specific addresses of criminal activity. For example, Weisburd and his colleagues (1991) analyzed one year of police calls-for-service data in Minneapolis, MN in order to identify addresses of crime events. They found that 5,538 addresses (out of 115,000) accounted for 20 or more "serious" crime calls in a year. Mapping and site observations assisted in clustering the addresses into 365 hot spots of crime, which accounted for 2.5% of the city's street segments or blocks, but nearly 25% of the annual crime.

The Illinois Criminal Justice Authority has developed statistical tools and procedures for clustering "hot spots" into "hot areas" based on law enforcement and community information. The advantage of these statistical tools is that they summarize and organize information in a useful manner. The statistical tools answer the question: "Where are the densest concentrations of incidents or events on the map?" (Block, 1993:33).

The knowledge that crime is more likely to occur in certain hot spots or hot areas has resulted in the consideration of *places* as important features in understanding crime. *Place* refers to a geographical area described by certain salient features: location, boundaries, function, control and size. In his study of places, Eck (1994) illustrates how place characteristics might account for or contribute to criminal activity. The concept of place is an important factor in understanding hot spots. For example, in a special study of robberies in San Diego, CA, analysts determined that robberies clustered in two different areas. In the midst of each area was a convenience store; the robberies were clustered around these places in the neighborhood. By analyzing places, it is possible to begin to address the question of why events occur in certain areas. For law enforcement agencies, the ability to map places and events can assist in understanding the relationships between crime and geographical features in an area.

Three trends have spurred the growth and interest in automated mapping in recent years. One trend is related to the microcomputer revolution over the last ten years, in which the capabilities of microcomputers have improved while costs have simultaneously decreased. Desktop microcomputers now have the computing and storage power of large mainframe computers that once filled entire (air-conditioned) rooms. Coupled with these hardware improvements, the second trend has been improved software mapping packages, such as MapInfo for Windows[1] and ArcInfo.[2] These packages facilitate automated mapping by providing a set of menus for the various tasks involved in making a map. The combination of faster microcomputers and mapping packages has provided police departments with new capabilities for compiling and analyzing data.

Improved computer resources are driving the final trend of improved geographic base files. An essential element of any automated mapping system is an accurate and complete geographic base file for converting street addresses to two-dimensional coordinates (x/y coordinates). Many local governments have now devoted funds and personnel to develop geographic base files (commonly called geobase files) to support mapping, not only for police departments but for other agencies such as fire, human services and transportation. Accurate geobase files are a valuable resource and have contributed to the growth in mapping. A second change centers on improved capabilities for transferring data from one system to another. It is now easier to merge databases into a single system so that maps of different types of data are possible. The result is a more complete picture of relationships among events, especially their geographical relationships.

The effects of these changes can be seen in many police departments. For example, each precinct in the Los Angeles, CA Police Department has a crime analysis unit that includes an analyst capable of using available microcomputer hardware and software. Analysts can download data from the department's central record system and analyze the data locally through a graphical user interface package. The interface package includes an inquiry capability to ask questions about crime in the precinct. Results of the inquiries can be shown as a pin map on the computer screen and can be printed. At the San Diego, CA Police Department, a centralized unit of crime analysts draws on data maintained in a drug information network system. This network accesses several different databases such as crime records, computer-aided dispatch data on drug complaints, citizen reports of drug dealing reported directly to the narcotics section, patrol intelligence data and other drug-related data. Analysts merge data from these systems into a geographical mapping package. The maps and supporting information sources are available to patrol officers and members of the narcotics unit. A third example is from the Dallas, TX, Police Department, which has merged census data into its record management system. Maps have been produced showing the relationships among violent crimes, drug trafficking areas and demographic characteristics of the city.

COMPUTER MAPPING TECHNIQUES

Computer mapping techniques can be divided into three broad categories: descriptive, analytical and interactive mapping. Descriptive mapping, the most basic type of automated map, shows crimes, calls for service, traffic accidents, and other data in a pin map or shaded area format. Two or more different types of events can be displayed to provide a complete picture of the problem. Analytical mapping starts with analysis of data, with the results displayed on the map. Identifying crime hot spots is a primary example of analytical mapping. Other examples involve special studies to apply statistical analysis techniques to spatial data and display the results in an automated map. Finally, interactive mapping allows a user to cycle through a series of steps to make queries against a database, map the results, make a decision on the basis of the maps and start anew through the cycle. Interactive mapping extends the capabilities of law enforcement agency by moving into continuous assessment and evaluation of information.

Descriptive Mapping

Police departments deal with a variety of address-specific data such as crimes, computer-aided dispatch records, arrests, traffic accidents, drug dealing locations, patrol observations, field interrogation records and others. A basic function of any automated mapping system is to replicate the pin maps that police departments have been using for many years. Automated maps are similar to pin maps in that data from various information sources are plotted. Individual symbols (like different colors of pinheads) are used for each type of event.

Figure 1 shows a map developed by the Jersey City, NJ Police Department for one area of the city. The map illustrates cocaine arrests (shown as boxes) and heroin arrests (circles) for 1991. It shows that cocaine and heroin are generally sold in different areas of the city. Cocaine is more pervasive since arrests occur in several locations, whereas heroin is more likely to occur along major thoroughfares. The Jersey City Drug Market Analysis project, in fact, found that the major artery and intersections were the main distribution points. This has implications for different police strategies designed to eradicate drug market activities. Since heroin points of sale are different from cocaine, the police can use this information to develop and implement different enforcement strategies (Weisburd and Green, 1993).

Figure 2 is a shaded, or choroplethic, map from the San Diego Police Department showing domestic violence calls for service per thousand population. The more heavily striped areas indicate higher rates of domestic violence calls. The map clearly shows higher rates of domestic violence calls in the southern part of the city. The department used the information to develop a strategic plan for dealing with domestic violence in these high rate areas. The plan includes different police responses in high incidence areas due to the concentration of events.

Finally, Figure 3 illustrates the use of places in descriptive mapping techniques. The map shows the relationship between places (e.g., convenience stores) and store robberies in San Diego in a six-month period. As shown in the map, the robberies tend to cluster around the convenience stores. Few robberies occur outside of the surrounding areas. This map highlights the importance of places in understanding crime events. By

Figure 1: Cocaine and Heroin Arrests in Jersey City, 1991

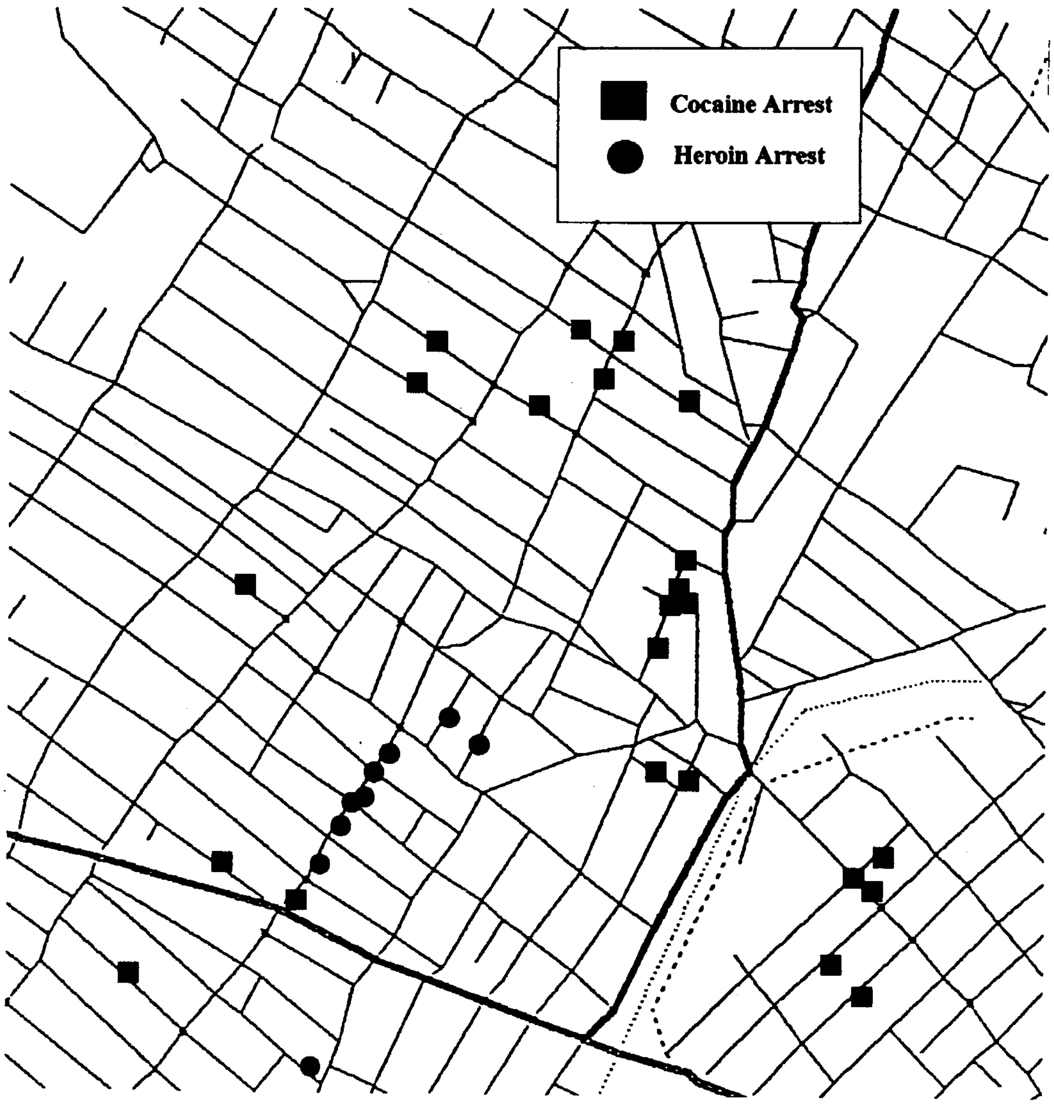


Figure 2: Domestic Violence Rates in San Diego by Census Tract, 1992

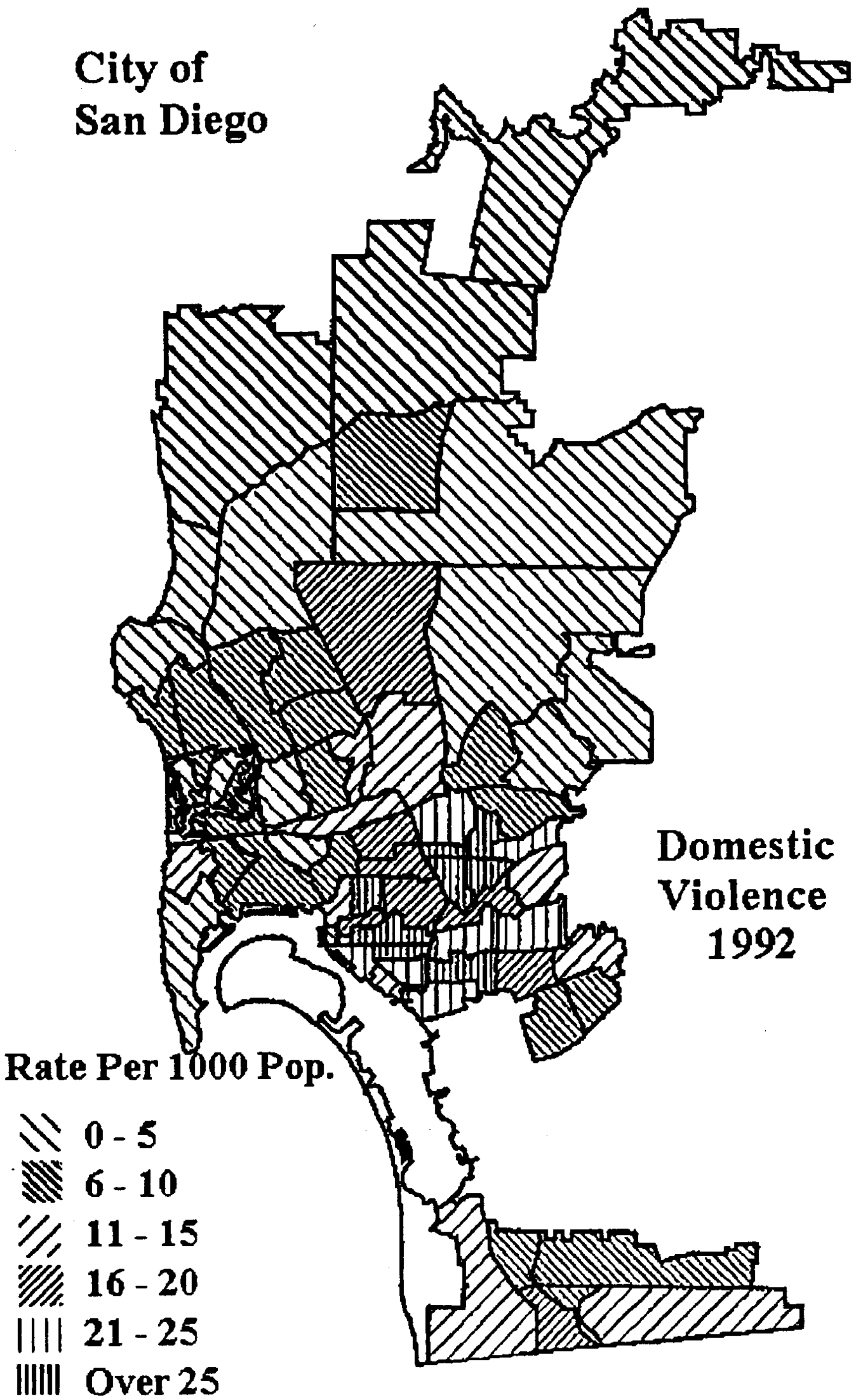
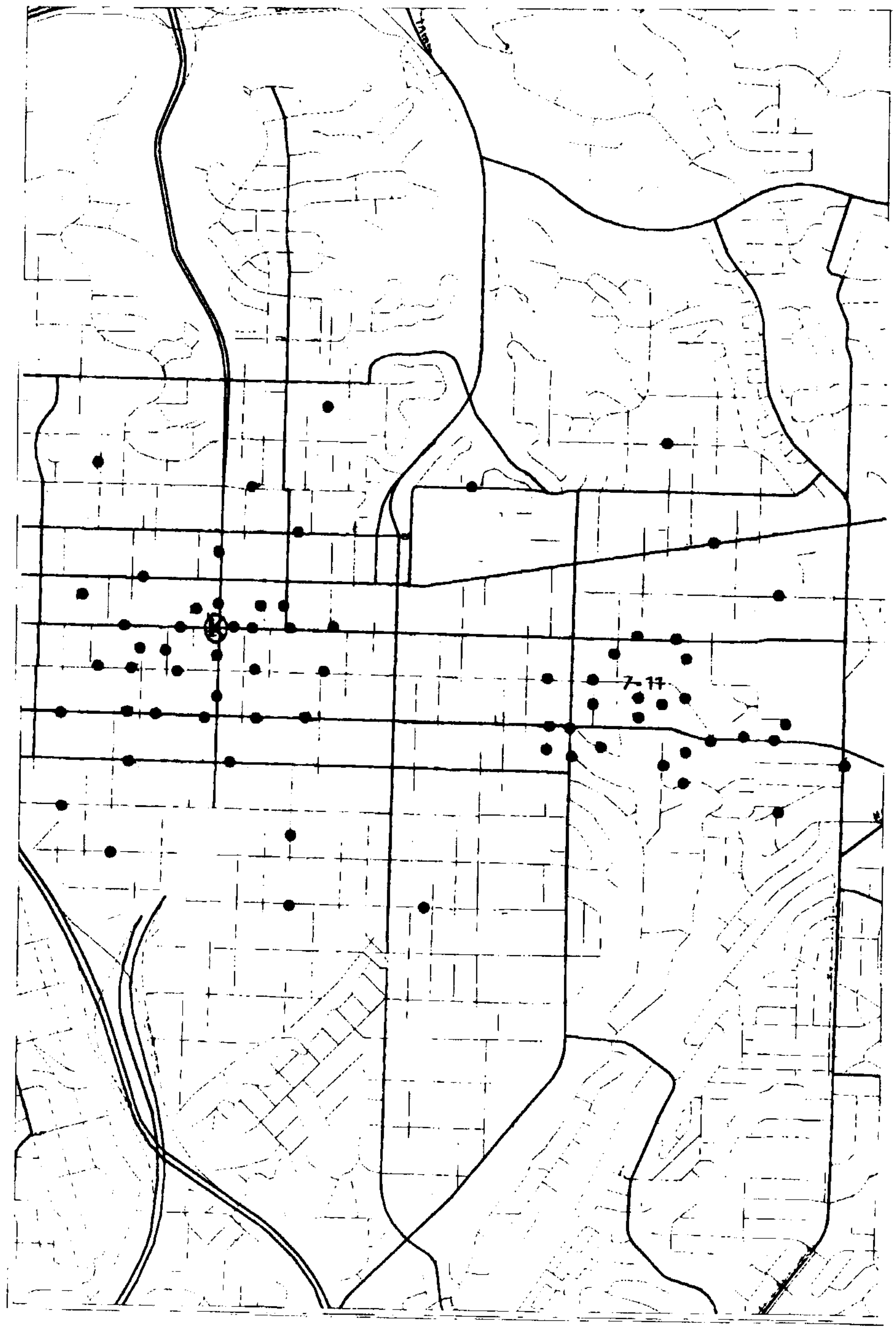


Figure 3: Convenience Store Robbery Clusters in San Diego



showing the location of the "key places" in the community, it is possible to illustrate how crimes are spatially related to place features.

Police departments can use descriptive maps to examine displacement effects resulting from a particular law enforcement strategy. For example, a "before" map will show the frequency of crime activities prior to an enforcement effort, and an "after" map of the same area will show the effects of the enforcement. The map may then visually show decreases in the area receiving the enforcement and movement of crime to surrounding areas.

The primary advantages of descriptive maps are that they are easy to produce and easy to understand. Large amounts of data can be turned into useful informational maps that benefit personnel at all levels of the department. For senior police administrators, the maps provide easily understood graphical presentations for elected officials and citizen groups. They also assist in developing responses to crime problems. For patrol officers, descriptive maps provide a much better format for seeing crime patterns than reviewing written reports.

These examples also illustrate an important feature of descriptive mapping—the ability to control the size of the geographic area under scrutiny through the mapping software. Maps can cover an entire jurisdiction or smaller areas. The user selects the geographic area desired by either selecting a predefined area (such as a precinct, reporting area or census tract) from a menu or by "zooming in" on an area of the city. The area of interest can literally range from a single block to an entire jurisdiction. This is important because it provides flexibility in examining the events of interest.

With descriptive mapping, it is possible to display the locations of different types of events such as drug markets that specialize in certain products (e.g., heroin, cocaine, marijuana, etc.) or robberies of different types of stores (e.g., gas stations, fast food chains, etc.). Descriptive mapping provides the ability to look at groupings of events in an easier manner than manual pin maps. These groupings of types of events are useful to detect trends or patterns. Further, the maps indicate the frequency or counts of events occurring in a given area in more detail than manual pin maps. Police departments can include this information in their internal bulletins describing crime problems. The bulletins can include both a map indicating the locations of the offenses and a list of common characteristics of the crimes. An officer needs to spend only a few minutes with these bulletins to understand where and how the crimes are occurring.

While descriptive maps are useful, they suffer from three potential problems. One is that it may not be easy to discern a pattern of crimes by looking at a pin map. This is true regardless of whether the pin map has been manually developed or is an automated map. Two viewers of the same pin map may identify different "patterns" of crimes.

A second problem centers on the difference between an address and a location. An address, such as an apartment or mobile home complex, contains many locations. As an example, the Tempe, AZ Police Department follows the same procedure as many other departments in producing monthly tabulations on locations with repeat calls for service. During 1993, one address had 496 calls for service including 40 family fights, 37 loud noise calls, 29 suspicious vehicle/person calls, 24 missing persons and 16 juvenile disturbance calls. The address is, in fact, a mobile home park with 370 units. A pin map will show this address as one large problem when it really consists of several small problems.

Finally, shaded maps sometimes are misleading from what is called the "boundary" problem. Shaded maps show distinct geographic areas, such as precincts, census tracts or reporting areas. An event on a border street between two areas is placed in one or the other area based on which side of the street it occurred. An event at an intersection of four areas presents an even greater classification problem. The consequence of the boundary problem is that patterns are lost as the volumes of events are distorted.

Analytical Mapping

Analytical mapping conveys data analysis results rather than merely mapping the individual data points. Analytical maps advance the ideas behind descriptive maps by including information that is helpful in understanding the trends or patterns of events. They require analyzing the data first, then mapping the results. Two examples will be discussed to illustrate analytical mapping and how it has been used by police departments:[3]

- Results of an analysis of gang-related violent crimes using the STAC (Spatial and Temporal Analysis of Crime) package developed by the Illinois Criminal Justice Information Authority through grants from the U.S. Bureau of Justice Assistance and,

- A spousal abuse study conducted by the Baltimore County, MD Police Department, which used mapping to identify potential areas of under-reporting.

As described in the Illinois Criminal Justice Information Authority (1993):

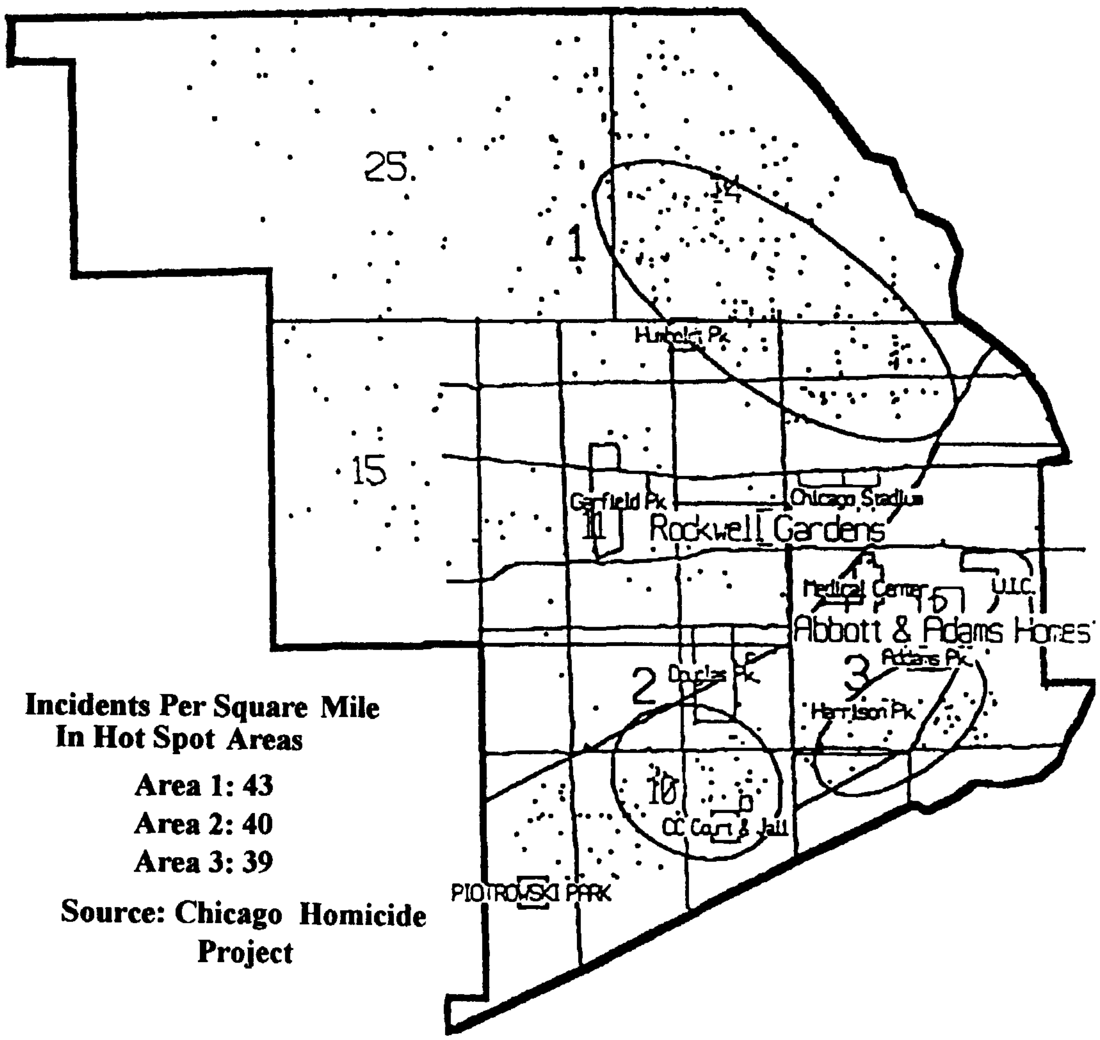
> • STAC contains both a Time Analyzer and the STAC/space modules, which is a toolbox for analyzing the distribution of events on a map. STAC/Space includes automatic searches for two kinds of Hot Spot Areas (Hot Spot Ellipse and Isocrime), and also Nearest Neighbor Analysis (a test of significance for clustering), Mean Center, and radial searches for events occurring around an address or other location. . .STAC is not a mapping package, but a toolbox of spatial statistics that is used to interpret your mapped data and turn the data into information for crime analysis and problem solving. After STAC calculates statistical summaries of the data's spatial distribution, such as Hot Spot Area Ellipses or Isocrimes, users can map these summaries using a mapping package [pp. 1-2).

STAC contains analytical and visual procedures that are useful to detect patterns. One such procedure is the Hot Spot Ellipse, which analyzes the actual geographical scatter of events and delineates areas with the densest clusters of actual events. The procedure writes the results to a file, which can be accessed by a mapping program to show the actual data and ellipses surrounding the concentrations of events. Figure 4 is an example showing street-gang-related violent crime for one police area of the Chicago Police Department. Three hot spots are shown on the map, as identified by the Hot Spot Ellipses procedure. These hot spots average about 40 incidents per square mile and are the highest concentrations of incidents in the mapped area.

With STAC, the Chicago Police Department, the Illinois Criminal Justice Information Authority and other agencies have developed an early warning system for violence. The system is designed to identify areas that are "at high risk for a surge in serious street-gang violence and homicide in time to save lives" (Illinois Criminal Justice Information Authority, 1993:5). Particular focus is on gang-related violent crime, as displayed in Figure 4, and other confrontation situations such as spousal arguments, fights between acquaintances, sexual assaults and robberies. With the knowledge of troubled areas, law enforcement departments can develop appropriate responses.

One such response is the Gang Violence Reduction Project, which provides community mobilization and social opportunities to gang members. This project involves a five-member gang outreach team that offers mediation and crisis intervention services to rival gangs in the community. The outreach team also provides referrals to education, job and other social service opportunities. Additionally, the Cook County Adult Proba-

Figure 4: Street-Gang Related Violent Crime Incidents Known to Police in and Around CPD Area Four, through July 1992, in Chicago



Incidents Per Square Mile In Hot Spot Areas

Area 1: 43
Area 2: 40
Area 3: 39

Source: Chicago Homicide Project

tion Department provides intensive supervision services to 150 gang members sentenced to probation. In summary, the STAC/Early Warning System identifies areas of high gang concentrations, and the intervention project begins its work with youths in the identified area.

A spouse abuse study by the Baltimore County Police Department provides another example of analytical mapping (Canter, 1990). The department's study had two objectives:

- Identify locations and areas within the county that were experiencing high volumes of spousal assault cases, and

- Develop a model that could be used to identify areas where cases may be occurring but are not reported.

The Spousal Abuse Unit within the police department is responsible for conducting follow-up investigations of abuse cases, notifying precinct stations of household in their areas with spouse abuse problems, identifying repeat offenders of spouse abuse and coordinating victim assistance with social agencies in the county. The unit provided data files for the study containing incident, victim and offender information on 3,874 spouse abuse cases from 1989. The database allowed for the identification of recurring events, victims and perpetrators. Descriptive mapping techniques were employed to satisfy the first objective of providing the unit with the identification of locations and areas having high volumes of spousal assault cases.

Our interest in the study, however, is in the second objective of identifying geographical areas where domestic violence may be occurring, but are underreported. The approach to this difficult objective was to first develop a multiple regression model relating social and demographic variables to spousal assaults. Data by census tracts provided the independent variables for the regression. After development of an adequate model, comparisons were made between the number of cases estimated by the model and the number actually reported to the police for each census tract. Census tracts where predictions were substantially greater than actual occurrences were candidates for areas with underreporting. A series of verification steps ensured that these areas did, in fact, experience underreporting. The following paragraphs provide more detail on this modeling approach as an example of analytical mapping.

The spouse assault records were first matched against a geobase file to determine the census tract for each incident. The number of cases in each of the 182 census tracts was calculated. Other police department and locally available census data were then merged into the aggregated census tract file.[4] Statistical analysis techniques identified three key variables related to the number of spouse abuse cases in a census tract:

- Drug-alcohol charges per 100,000 population
- Number of renters in the census tract
- Unemployment rate

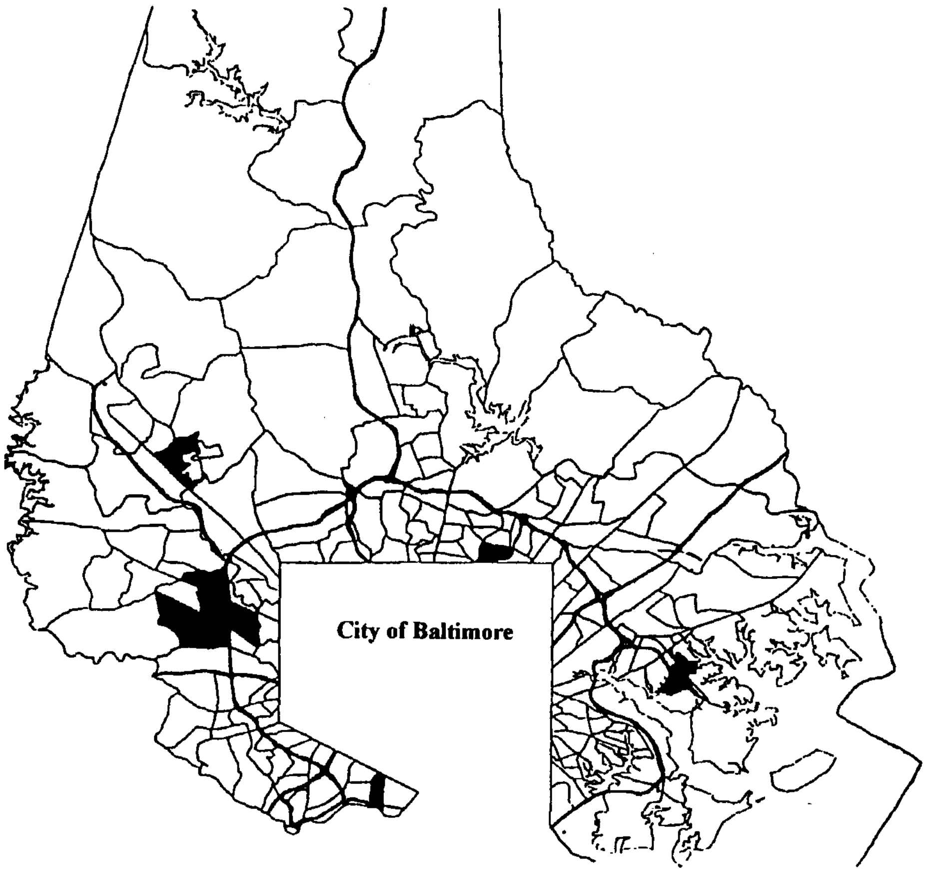
The multiple regression analysis revealed that each variable was positively related to spousal assaults. That is, the number of spousal abuse cases tended to be higher in census tracts with high volumes of drug and alcohol arrests, high numbers of renters in the census tract, and high unemployment rates. Conversely, the number of cases tended to be low in census tracts with low values for these three variables. The regression model had an adjusted R value of .632, which indicates a reasonably good model.

One area of concern, which was not reflected in the favorable R^2 value, was whether the model had deficiencies due to the correlation in the spatial distribution of the cases, a phenomena referred to as spatial autocorrelation. That is, a geographic area with a high value tends to have neighboring areas with high values, and vice versa. A test known as Dacey's test (Norcliffe, 1977) specifically addresses whether spatial autocorrelation exists, and the results of the test, when applied to the regression model, indicated no significant spatial autocorrelation. This result, coupled with the favorable R^2 value, provides good support for saying that the regression is a reasonable representation of the levels of spouse abuse cases in the census tracts.

To determine the areas of underreporting, the residuals from the model were calculated.[5] Figure 5 shows a map of the census tracts with positive residual values greater than 30. That is, the model's estimates of spousal abuse events for these census tract were at least 30 cases higher than the actual number of reported cases. The residuals identify five potential areas where spousal abuse events are likely to occur more than the reported events.

The police analysts reached the important conclusion that these areas were candidates for underreporting of spouse abuse cases—a conclusion based on two aspects of the regression model. First, the model estimated significantly higher numbers of cases for these areas as indicated by the residuals. Second, Dacey's test showed no significant spatial autocorrelation. As a consequence, a plausible explanation for the overestimation by the model is that cases were simply not reported by victims in these areas. This result was supported by interviews of patrol officers assigned to these areas and follow-up activities by the Spousal Assault Unit. Patrol officers

Figure 5: Residuals from Regression Model in Baltimore County: Areas with High Residual Values



(NOTE: Dark areas had residuals greater than 30.)

provided reasons that underreporting could be occurring in these areas based on their perceptions of the community. The police reported that many families in these areas believe the police would not take any action in their cases. In the large underreported area on the west side of the county, the Spousal Assault Unit distributed leaflets advising that spouse abuse was a convictable offense and that the unit was concentrating in the area. The area subsequently showed an increase in reported cases to the police.

The analysis assisted in pinpointing areas where spousal assault could be a problem. While the analysis may not be entirely conclusive because the true amount of underreporting can never be determined, the map clearly indicates that these target areas are different and need attention. The maps helped the police department develop follow-up techniques that were proactive, instead of reactive.

Analytical mapping expands on what can be accomplished with spatial data. It provides a means of developing models for exploring data trends, particularly geographic trends, and testing hypotheses about underlying relationships. Analytical mapping generally requires the development of specialized data bases or information sources that can be used to understand the trends. It provides the police department with tools to identify patterns and predict events to guide proactive police strategies. Analytical mapping therefore integrates the descriptive mapping with other information that is critical to improving police responses. Analytical mapping usually is preceded by a special study that requires the development of the necessary information sources. However, once the information sources are developed, the department can maintain them to provide ongoing analysis and mapping of results. A linkage must always be established between the analysis and the automated mapping system.

Interactive Mapping

The final type of mapping is interactive mapping. This type of mapping involves both descriptive and analytical techniques in a forum that allows the user to ask "what if" questions and see the results automatically. With interactive mapping, a department is capable of performing ongoing analysis of information without the need to conduct special studies. We offer two examples of interactive mapping. The first is a system called HyperCube III, which assists police departments in forming patrol beats;

the second is an inquiry system developed by the Pittsburgh, PA Police Department to assist investigators in solving drug trafficking cases.

The HyperCube III program is based on a mathematical queuing model that uses the precinct s geography to predict several performance measures for its patrol units:

- Average travel time and response time for the entire region and for each reporting area.
- Workload and average travel time for each response unit.
- Region-wide workload imbalance.
- For each unit, the percentage of its assignments that require the unit to travel to another precinct.

To form patrol beats using the HyperCube III program, an analyst provides data on the number of calls in small geographic areas. Usually these are the police reporting areas in a precinct. The user must provide the boundaries of these areas and the average travel time between pairs of reporting areas. More importantly, the user groups the reporting areas into patrol beats as the analysis unit.

The HyperCube III program shows the results on a screen map of the precinct with several pictorially appealing displays. Each patrol unit is shown as an icon, with its size proportional to its workload. Reporting areas are colored based on the average travel time, with red as high travel time areas and green as low travel time areas. A bar under each unit shows how its average travel time compares to other units. Finally, a unit's response pattern is displayed showing where the unit is dispatched most often.

Based on the screen map results, the user can change beat configurations by moving reporting areas from one beat to another. This is done interactively, and the model refreshes itself and visually displays the results. With this approach, the analyst interactively creates beat configurations and quickly sees the results of new beat designs. The results are shown relative to changes in average response time and workload. This means that a police department can alter beat configurations based on efficiencies in workload and response times.

P-DMAP is an interactive mapping developed by the Pittsburgh Police Department under its Drug Market Analysis Program, a national demonstration and evaluation project funded by the U.S. National Institute of Justice. The P-DMAP project is housed within the department's Office of Organized Crime, Narcotics, and Intelligence. With support from the Heinz School of Public Policy and Management at Carnegie-Mellon University, the department has developed the P-DMAP automated information system as a tool to support investigations of drug trafficking and other drug-related cases. The system resides on a Sun SPARC work station and uses Arclnfo for its automated mapping.

The P-DMAP system combines data from many different sources to create a composite of information on events, offenders, co-offenders, addresses and locations, and other critical information that could be beneficial to investigations. The Computer Aided Dispatch (CAD) system provides data on calls for service, and the Public Safety Management System provides arrest data. The P-DMAP system also contains property ownership data from a database maintained by the city's tax assessment department. Calls for service are downloaded to the P-DMAP system, usually on a bimonthly basis, and arrests are downloaded weekly. Property ownership information is downloaded about every six months.

The P-DMAP system is both an inquiry and a mapping system. It can be queried, for example, by name, address, special locations (e.g., Three Rivers Stadium), drug market area and school. Name inquiries can includes arrestees, co-offenders and victims. Depending on the query, it is possible to locate appropriate records in the integrated databases. For example, an inquiry by arrestee name identifies records wherever the arrestee appears in the arrest database (as an arrestee or as a victim), calls-for-service database (as a caller) and the property-file database (as a landowner). This is a potentially powerful tool for examining patterns of interactions and possible locations where a person could be located. The search capability is an extremely powerful tool for investigators and police officers because it reduces reliance on memory and allows for examination of related information on offenders. The same is true for locations. Information about locations can be gathered by querying all the databases to identify how often the location was a site for a call or arrest, what the dates were, what time of day the call or arrest was made and who owns the property.[7]

When the system locates all the records satisfying the inquiry, the associated locations can be displayed as a screen map. At this point, an investigator can select a location on the screen map and view all records associated with the location. These records appear on the right side of the screen. The results usually provide an investigator with additional information that leads to another inquiry and screen map. For example, a record may show the names of other arrested persons and subsequent inquiries can be made about these persons. The map may also reveal a geographic pattern of calls or arrests for a person. Since all information is in one automated computer system, it has become a valuable tool in police investigations.

Through this interactive process, an investigator develops leads for a case. Some leads may come directly from the inquiry results, while others will be based on the geographic distribution of incidents as shown on the screen map. In the latter instance, an area may be identified where the investigator should go to ask more questions. The point is that the mapping system provides a mechanism for improved investigations. It also provides the ability to examine patterns, disprove assumptions and obtain factual information.

In summary, interactive mapping offers a means of performing analysis or solving problems in a real-time mode. It requires a supporting computer system that is capable of obtaining inquiring parameters from a user and performing an analysis based on the parameters. The results are displayed as a screen map that may, in turn, generate another cycle of inquiry.

DEVELOPING A COMPUTER MAPPING CAPABILITY

The previous section has been devoted to identifying the different uses of mapping within a law enforcement environment. The different capabilities—descriptive, analytical, and interactive mapping—have distinct characteristics. For police departments, these provide a potential to use technology to improve operations, with each making different contributions to the enhancement of policy strategies. Underlying each capability is an automated mapping system. To some extent, the characteristics and nature of the automated system define the extent to which a police department can use descriptive, analytical, and interactive mapping. In this section, we provide an overview of automated mapping capabilities and the extent to which the mapping system can be used within a department.

An automated mapping system consists of three primary components:

- Hardware and software for mapping
- Geobase file
- Data integration software

Microcomputers and minicomputers have become the hardware of choice for most police departments that develop automated mapping. Cost often influences the decision, but the increased power of hardware is also a contributor. Many police departments are becoming increasingly familiar with microcomputers and are comfortable in using them. New technology has also provided easier ways of communicating with other computers. The communication systems have eased the sharing of data. Most systems include either a laser printer or plotter for producing hard copies of maps.

The Maplnfo and Arclnfo software packages appear to be the most popular for manipulating data and producing maps. However, other geographic information systems have started to appear on the market. The basic functions of these systems are to (1) match addresses against a geobase file to obtain coordinates, (2) maintain boundary files for mapping precinct boundaries, census tract boundaries, communities, or other geographic breakdowns of the jurisdiction, and (3) provide the user with an easy way of selecting a geographic area and a set of data to be mapped. The results are displayed initially as a screen map, which can then be sent to a printer or plotter for hard copy output.

As previously indicated, a geobase file is a necessity in automated mapping systems. The file contains the cartographic data necessary for producing a screen map, as well as attributes of the geography represented by a map, such as address ranges of a street segment, intersections of streets and boundaries of geographic areas. The most common geobase files are the TIGER files developed by the Census Bureau for the 1990 census.[8] TIGER files contain topological data structures describing how points and lines relate to each other on a map to define geographic areas. Six types of records exist with TIGER files for describing shapes, street names and other information needed for mapping.

Data integration software provides the important function of combining data files from several sources into one location for mapping. These data files typically reside on other systems, usually mainframe systems. The role of data integration is to access these files, extract the data needed, download the data and convert the data into a format accessible by the mapping system.

We would be remiss, however, if we did not discuss some of the problems associated with developing these systems. The two most significant problems are in establishing a geobase file and setting up the software system.

With regard to the geobase files, the TIGER files are notorious for their errors and omissions. In fact, the authors have yet to find a jurisdiction that was pleased with what they received in their TIGER files. This is not to say that TIGER files should be avoided, but rather that a user must be prepared to devote considerable effort to correct the files. That is, it is necessary to verify the coordinates so that they are as accurate as possible. In addition, new streets must be added to the files. In Jersey City, NJ, the police department spent nearly six months verifying streets, intersections and addresses. While they found the initial files to be 85% accurate, changes were needed to achieve the optimal results from their mapping system. In some jurisdictions, a more recent geobase file may be available in another agency, and the police department should take advantage of these files.

The second major problem is in setting up the software system. Most systems require the user to develop menus for producing maps. This is a one-time effort, but it may require the assistance of a programmer. A related one-time effort is that the user must develop files reflecting the boundaries of areas, such as precincts or census tracts. The inputting of geographical references is critical in developing the data in a usable manner.

There are other related problems that should be mentioned. One is the retention of key personnel supporting the mapping systems. Department analysts usually have the responsibility for developing a system, and their expertise grows rapidly as applications are developed. Other governmental agencies and private companies also use mapping systems, and personnel for operating and maintaining these systems are in demand. It is essential to recognize that maintenance is an important component of any automated system, and resources must be devoted to sustain the system. Another problem is the need to train others in the department on how to use the system. The developer should not be the only person who knows how to produce maps. Indeed, training others in the department will increase system usage.

With these problems in mind, the advice to potential users of these systems falls along the following lines:

- Start small.
- Integrate the mapping application into existing systems.
- Plan early on integrating other data files for mapping.

Mapping crime data is a good starting point. Most departments initially acquire mapping software for crime analysis, and the automation of manual pin maps is certainly a major step forward. After getting experience with mapping crime data, the department can expand the types of data for the system. The mapping applications should not, however, be stand-alone systems. Instead, they need to be included in the department's overall records management or information system. Mapping should be another tool in the arsenal, just as management information systems draw on a variety of data for reports. Finally, integrating other data files into the mapping system opens up many more opportunities for developing more insightful maps. Calls for service, arrests, citizen hot line complaints and many other types of data can be integrated to show a complete picture of police needs in an area.

WHAT THE FUTURE HOLDS

Automated mapping systems offer potential for having major impacts on the strategies and tactics of police departments. Most importantly, the maps provide an approach to examine issues, information and problems with existing information. Automated mapping provides the mechanisms to train staff in how to use information differently in police departments, especially the use of information to develop effective police responses. In most cases, these responses can be in the form of proactive policing or mobilizing the community to address crime related issues.

The mapping systems offer new ways for departments to approach problems. Without a mapping system, department personnel tend to analyze crime problems on the basis of incident characteristics such as time of day, day of week and method of entry, with insufficient attention to the spatial aspects of crimes. These spatial aspects are important because they focus on clustering of events in locations, the time of the day of occurrence and the linkage among events.

We have already indicated the use of these systems for supporting community policing by producing maps of incidents in a community. While the maps are not the entire impetus, they assist in fostering positive relationships between officers and citizens in developing joint efforts against community problems. The same phenomena can occur in a wider arena in which interagency cooperation increases between the police department and other jurisdictional agencies. In Baltimore County, 16 county agencies have acquired the Maplnfo software. Representatives from these agencies meet monthly to discuss technical issues associated with the package and their ongoing applications. An interesting by-product of these meetings is that the agencies have started to exchange data so that more complete maps can be developed on particular problems. The potential result of these actions is that political boundaries will not be imposed on the definition of crime problems that can be critical in creating interagency responses to them.

Another important function of information systems, including mapping systems, is that they serve as the institutional memory for police departments (Maltz et al.. 1990). One of the difficulties faced by all police departments is constant turnover in personnel, either because of transfers to another unit or terminations from the department. Information systems fill a need for new personnel assigned to an area by providing historical information. Mapping systems fall into this same category. An officer assigned to a new beat can become familiar with area problems through automated maps showing crime problems, calls for service, traffic accidents and much more. In Pittsburgh, new investigators rely on the P-DMAP system to obtain information about cases and offenders.

The integration of databases and mapping capabilities also serves to strengthen a police department's responses to crime problems. With the advances in mapping technologies, and the coordination of researchers and police officers working together to understand crime, police departments are moving into a new horizon of problem solving. The three types of mapping are premised on some analytical and statistical principles that researchers use. Technology has afforded the opportunity for these analytical and statistical technologies to become available for police departments to use in examining crime problems. For example, descriptive mapping is based on the techniques of frequency distributions or counting, which is usually the beginning of an analytical inquiry. Mapping offers one way of displaying the results of the frequency distribution in a manner that is easy to understand (instead of using a running list of numbers). Inferential statistical techniques can also be used, as suggested by the Baltimore County spousal abuse study. The maps provide the vehicles to display the results.

Finally, as police become more involved in community policing and problem-solving initiatives, information is going to be key. Maps provide police officers and communities with critical information that is easy to understand. The maps can be shared with the community to develop cohesive and collaborative efforts. Within the police department, the use of information, and maps particularly, can be critical in empowering the police to work on crime problems. The police officer, armed with easy-to-understand maps describing and analyzing the crime issues, can then become more responsible for developing proactive strategies.

Officers will have consistent, well-defined information to guide actions. Information will be integrated into maps to provide incentives to provide new and creative responses. At the patrol officer level, this is critical to the achievement of a community policing philosophy, where the officer becomes a partner with the community in addressing crime problems. The maps provide the tools to focus on the critical issues. Mapping technology, therefore, has the potential for instituting change within police departments by providing officers with critical information that can be used to guide police and community strategies. Mapping, like other forms of technology, will be critical in advancing police organizations to make them more effective and efficient in the coming years.

NOTES

1. Maplnfo for Windows is a mapping system for microcomputers developed by Maplnfo Corporation, based in Troy, NY.

2. Arclnfo is a mapping system that operates on several computer platforms. Arclnfo was developed by the Environmental Systems Research Institute (ERSI), located in St. Paul, MN.

3. A more detailed example of analytical mapping can be found in an application developed by Rossmo, described in this volume.

4. Over 50 social and demographic variables were merged into the file. Some variables came directly from prior Bureau of Census publications while others were developed by the Baltimore County Planning and Zoning Commission, the police department, and the Maryland Department of Economic and Employment Development.

5. The residual for a census tract is the numeric difference between the estimate from the regression equation and the actual number of cases in the census tract.

6. The Hypercube model was developed by Dr. Richard C. Larson, a professor at the Massachusetts Institute of Technology and co-founder of the Queues Enforth Development Corporation. His work on the model began in 1974 and the model has been used as a planning tool in numerous jurisdictions in the U.S. as well as by police departments in several other countries.

7. Some police departments maintain separate computer systems that allow for the inquires that have been integrated into this system. The key characteristic of the Pittsburgh system is the ability to conduct interactive searches among different data bases and map the information. Other departments have separate systems which allow for the transferring of data for mapping. For example, the San Diego Police Department has separate data bases for arrests, calls for service, hot lines, etc. which can be individually inquired. The information from these searches can then be transferred to the mapping system. The disadvantage is that this is less interactive and requires more computer expertise.

8. The term *TIGER* is an acronym for Topologically Integrated Geographic Encoding and Referencing.

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